particles) by countercurrent contacting of steam, introduced to the bottom of stripper 9 through a steam distributor 10. The spent catalyst is then transferred to regenerator 17 via the spent catalyst standpipe 13a and lift line 15**.** Spent catalyst slide valve l3b, located on spent catalyst standpipe 13a is used for controlling catalyst flow from stripper 9 to regenerator 17. A small portion of combustion air or nitrogen may be introduced through a distributor 14 to help smooth transfer of spent catalyst.

[0099] Coked or spent catalyst is discharged through spent catalyst distributor 16 in the center of the dense regenerator bed 24. Combustion air is introduced by an air distributor 18 located at the bottom of regenerator bed 24. Coke deposited on the catalyst is then burned off in regenerator 17 via reaction with the combustion air. Regenerator 17, for example, may operate at a temperature in the range from about 640°C to about 750°C and a pressure in the range from about 1 barg to about 5 barg. The catalyst fines entrained along with flue gas are collected in first stage cyclone 19 and second stage cyclone 21 and are discharged into the regenerator catalyst bed through respective dip legs 20, 22. The flue gas recovered from the outlet of second stage cyclone 21 is directed to flue gas line 50 via regenerator plenum 23 for downstream waste heat recovery and/or power recovery.

[00100] A first part of the regenerated catalyst mixture is withdrawn via regenerated catalyst standpipe 27, which is in flow communication with J bend 1. The catalyst flow from regenerator 17 to reactor 3 may be regulated by a slide valve 28 located on regenerated catalyst standpipe 27. The opening of slide valve 28 is adjusted to control the catalyst flow to maintain a desired top temperature in reactor 3.

[00101] In addition to lift steam, a provision may also be made to inject feed streams such as C_4 olefins and naphtha or similar external streams as a lift media to J bend 1 through a gas distributor 1a located at the Y-section for enabling smooth transfer of regenerated catalyst from J bend 1 to reactor 3. J bend 1 may also act as a dense bed reactor for cracking C_4 olefins and naphtha streams into light olefins at conditions favorable for such reactions, such as a WHSV of 0.5 to 50 h^{-1}, a temperature of 640°C to 750°C, and residence times from 3 to 10 seconds.

[00102] A second part of the regenerated catalyst mixture is withdrawn into a second reactor 32 through a standpipe 30. A slide valve may be used to control the catalyst flow from regenerator 17 to second reactor 32 based on a vapor outlet

seconds. When different feeds are introduced, preferably the C_4 feed is injected at an elevation below light naphtha feed injection, and the light naphtha feed injection is at an elevation below the heavy naphtha feed injection. Where used, a medium naphtha feed injection would be intermediate the elevation of the light and heavy naphtha elevations.

[00111] As necessary, make-up catalyst may be introduced via one or more flow lines 42, 43. For example, fresh or make-up FCC or Y-type zeolite catalyst or a mixture of these two may be introduced to regenerator 17 via flow line 42 and fresh or make-up ZSM-5/ ZSM-11 catalyst may be introduced to second reactor 32 via flow line 43. Overall system catalyst inventory may be maintained by withdrawing mixed catalyst from regenerator 24, for example. Catalyst inventory and accumulation of the preferred catalyst within reactor 32 may be controlled, as will be described below, via control of the reactor and separator 47 operations.

[00112] In some embodiments, a first part of the regenerated catalyst is withdrawn from regenerator 17 into a Regenerated Catalyst (RCSP) hopper 26 via withdrawal line 25, which is in flow communication with regenerator 17 and regenerated catalyst standpipe 27. The catalyst bed in the RCSP hopper 26 floats with regenerator 17 bed level. The regenerated catalyst is then transferred from RCSP hopper 26 to reactor 3 via regenerated catalyst standpipe 27, which is in flow communication with J bend 1. The catalyst flow from regenerator 17 to reactor 3 may be regulated by a RCSP slide valve 28 located on regenerated catalyst standpipe 27. A pressure equalization line 29 may also be provided. A similar feed system may also be used to provide catalyst to the second reactor 32.

[00113] A separator bypass line may also be used to facilitate the transfer of particles from the top of reactor 32 to the vessel 8. Second reactor 32 utilizes two different catalysts that may differ in one or both of particle size and density, such as a lighter and/or smaller Y-type zeolite or FCC catalyst and a larger and/or denser ZSM-5/ ZSM-11 shape-selective pentacil small pore zeolite. The superficial gas velocity in second reactor 32 may be maintained such that essentially all of the lighter, smaller catalyst (e.g., Y-type zeolite / FCC catalyst) and a portion of larger and /or more-

dense catalyst (e.g., ZSM-5 / ZSM-11) is carried out of the reactor with the cracked hydrocarbons and steam recovered via flow line 45.

[00114] The effluent from reactor 32 recovered via flow line 45 may thus include cracked hydrocarbon products, unreacted hydrocarbon feedstock, steam (stripping media), and a catalyst mixture, including essentially all of the lighter, smaller catalyst and a portion of the larger and/or more-dense catalyst introduced to the reactor. The effluent may then be transported via flow line 45 to a solids separator 47. Separator 47 may be a separator configured to separate the two types of catalyst based on their physical properties, namely particle size and/or density. The separator 47 is operated at hydrodynamic properties that enhance the separation of the two types of catalyst based on their physical properties.

[00115] After separation in separator 47, the smaller/lighter catalyst (Y-type zeolite / FCC catalyst) is then transported from separator 47 to the common disengager or containment vessel 8, housing the riser reactor cyclones and/or reaction termination system, via outlet line 36a. The larger and/or denser catalyst (ZSM-5 / ZSM-11) may be returned to the mixed flow reactor 32 for continued reaction with hydrocarbon feeds introduced through distributors 34.

[00116] Continuously or intermittently, a portion of the effluent containing both types of catalysts being transported via flow line 45 may be diverted to bypass separator 47. The diverted portion of the effluent may flow around separator 47 via a flow line (not illustrated), which may include a diverter or flow control valve. The effluent may then continue via a flow line back to disengager 8 for separation of the hydrocarbon products from the catalysts, such as being combined with the effluent and smaller catalyst recovered from separator 47 via flow line 36a, and may be introduced either upstream or downstream of quench 36b. Alternatively, the diverted effluent may be fed directly to disengager/ containment vessel 8.

[00117] Embodiments herein contemplate use of y-shaped flow conduit or similar apparatus (not illustrated) to continuously send a portion of the effluent, containing both catalyst particle types, to disengager 8, while continuously sending a portion of the effluent to separator 47, thus allowing for the desired accumulation of the larger and/or denser catalyst particles within reactor 32. The catalyst from the second reactor bottoms can also be transferred via

line 37 the regenerator 17. Blower air is used as carrier gas to transfer the catalyst to regenerator 17. Such catalyst transfer facility will not only help in controlling the catalyst bed level in reactor 32 but also help in more frequent catalyst regeneration. The use of increased flow of carrier fluid and/or the use of a flow diverter, as described above, may beneficially provide for the accumulation of the catalyst selective for cracking naphtha range hydrocarbons in the second reactor, reactor 32.

[00118] Embodiments disclosed herein, by the methods described above, significantly increase the concentration of desired catalysts in the secondary reactor (motive bed or transport reactor vessel 32), consequently increasing light olefin yield. In addition, this process also serves as a method to decouple the withdrawal and addition of the ZSM-5 and ZSM5-11 with the withdrawal and addition of FCC catalyst. In summary, the FCC process presented in this disclosure creates a desired ZSM-5 or ZSM-11 catalyst additive rich environment in the secondary reactor 32, which could preferentially convert light and heavy naphtha products, such as those derived from primary reactor, to improve light olefin yield, while simultaneously maximizing middle distillate yield, by applying optimum operation condition in the primary reactor or riser.

[00119] Another benefit of embodiments disclosed herein is that the integrated two-reactor scheme overcomes the heat balance limitations in the stand alone C_4 / naphtha catalytic cracking processes. The secondary (mixed flow) reactor acts as a heat sink due to integration with the catalyst regenerator, minimizing the requirement of catalyst cooler while processing residue feed stocks.

[00120] The product vapors from the secondary reactor are transported into the first stage reactor / disengaging vessel or reaction termination device wherein these vapors are mixed and quenched with the products from the first stage and or external quench media such as LCO or steam to minimize the unwanted thermal cracking reactions. Alternatively, the product outlet line of the motive bed or transport reactor / solids separator can also be used to introduce additional quantity of heavy feed or re-route part of the feed from the first stage reactor (the riser reactor). This serves two purposes: (1) the catalyst in the solids separator vapor outlet line is predominantly Y-type zeolite / conventional FCC catalyst that is preferred to crack these heavy feed

CLAIMS

What is claimed:

1. A process for conversion of hydrocarbons, comprising:

   separating an effluent from a moving bed reactor, the effluent being at a reactor outlet temperature and comprising a reaction product, a first particulate catalyst, and a second particulate catalyst, wherein the first particulate catalyst has a smaller average particle size and/or is less dense than the second particulate catalyst, to recover a first stream comprising the reaction product and the first particulate catalyst and a second stream comprising the second particulate catalyst;

   admixing the second stream comprising the second particulate catalyst with a regenerated catalyst stream, the regenerated catalyst stream comprising first particulate catalyst and second particulate catalyst at an elevated temperature, wherein the admixing produces a mixed catalyst at a temperature intermediate the elevated temperature and the reactor outlet temperature;

   contacting, in the moving bed reactor, the mixed catalyst and a light naphtha feedstock to endothermically react hydrocarbons therein, the endothermic reaction reducing a temperature of the mixed catalyst to a second intermediate temperature;

   contacting, in the moving bed reactor, the mixed catalyst at the second intermediate temperature and a heavy naphtha feedstock to react hydrocarbons therein;

   recovering from the moving bed reactor the effluent comprising the reaction product, the first particulate catalyst, and the second particulate catalyst.

2. The process of claim 1, wherein the moving bed reactor is a vertical reactor, and wherein the light naphtha feedstock is introduced to the reactor at a lower elevation than the heavy naphtha feedstock.

3. The process of claim 1, wherein:

   the elevated temperature is in the range from 1300°F to 1500°F;

   the first intermediate temperature is in the range from 900°F to 200°F;

   the second intermediate temperature is in the range from 00°F to 1150°F; and

   the reactor effluent temperature is in the range from 700°F to 1150°F.

4. The process of claim 1, wherein the admixing is performed in the moving bed reactor at an elevation below an elevation at which the light naphtha feedstock is introduced.
5. The process of claim 1, wherein the admixing is performed external to the moving bed reactor.
6. A system for performing chemical reactions, comprising:

a separator configured to separate a reactor effluent comprising a reaction product, a first particulate catalyst, and a second particulate catalyst, wherein the first particulate catalyst has a smaller average particle size and/or is less dense than the second particulate catalyst, to recover a first stream, comprising the reaction product and the first particulate catalyst, and a second stream, comprising the second particulate catalyst;

a mixing device configured to intimately contact the second stream comprising the second particulate catalyst with a catalyst stream, the catalyst stream comprising first particulate catalyst and second particulate catalyst at an elevated temperature, wherein the intimately contacting produces a mixed catalyst at a uniform temperature intermediate the elevated temperature and a reactor outlet temperature, wherein the mixing device comprises a standpipe comprising:

a first inlet to receive the second stream from the separator;

a second inlet to receive the catalyst stream from a catalyst regenerator; and

an outlet to supply the mixed catalyst to a moving bed reactor;

the moving bed reactor configured to:

contact the mixed catalyst with a first reactant at the intermediate temperature, reducing a temperature of the mixed catalyst to a second intermediate temperature;

contact the mixed catalyst at the second intermediate temperature with a second reactant;

a flow stream configured to recover the reactor effluent from the moving bed reactor at the reactor outlet temperature.

7. The system of claim 6, wherein the mixing device comprises:

a first catalyst distributor disposed in a lower portion of the moving bed reactor, the catalyst distributor configured to receive the second stream from the separator and to disperse the second catalyst contained in the second stream into the moving bed reactor;

a second catalyst distributor disposed proximate the first catalyst distributor configured to receive the catalyst stream from the catalyst regenerator and to disperse the first and second catalysts contained in the catalyst stream into the moving bed reactor and into contact with the second catalyst from the first catalyst distributor.

8. The system of claim 7, further comprising a gas distributor positioned below the first and second catalyst distributors configured to fluidize and intimately mix the catalysts to attain the uniform intermediate temperature prior to contact with the first reactant.

9. The system of claim 7, further comprising structure internal to the moving bed reactor and located below a feed elevation of the first reactant to enhance contact of the catalysts to attain the uniform intermediate temperature prior to contact with the first reactant.

10. A process for conversion of hydrocarbons, comprising:

feeding a catalyst stream comprising a first particulate catalyst and a second particulate catalyst to a reactor, wherein the first particulate catalyst has a smaller average particle size and/or is less dense than the second particulate catalyst;

feeding a light naphtha feedstock and a heavy naphtha feedstock to the reactor, wherein the light naphtha feedstock is introduced to the reactor at a lower elevation than the heavy naphtha feedstock;

contacting the light and heavy naphtha feedstocks with the first and second particulate catalysts to react hydrocarbons contained therein;

recovering an overhead product from the reactor comprising a converted hydrocarbon effluent, the second particulate catalyst, and the first particulate catalyst;

separating the second particulate catalyst from the overhead product to provide a first stream comprising the first particulate catalyst and the converted hydrocarbon effluent and a second stream comprising the separated second particulate catalyst;

returning the separated second particulate catalyst in the second stream to the reactor.

11. The process of claim 10, wherein:

the catalyst stream is at a temperature in the range from 1300°F to 1500°F;

the contacting the light naphtha feedstock is at a temperature in the range from 900°F to 1250°F;

the contacting the heavy naphtha feedstock is at a temperature in the range from 850°F to 1200°F;

the overhead product stream is at a temperature in the range from 700°F to 1150°F.

12. The process of claim 11, further comprising admixing the catalyst stream and the second stream to provide a mixed catalyst stream having a uniform temperature in the range from 900°F to 1250°F.
13. The process of claim 10, further comprising recovering a bottoms product from the reactor comprising the second particulate catalyst.
14. The process of claim 10, further comprising:

    feeding a hydrocarbon feedstock and a mixture of first particulate catalyst and second particulate catalyst to a second reactor;

    contacting the mixture of first and second particulate catalysts with the hydrocarbon feedstock to crack the hydrocarbon feedstock and form a second reactor effluent comprising lighter hydrocarbons and a mixture of first and second particulate catalysts;

    feeding both of the first stream and the second reactor effluent to a separator;

    separating the first and second particulate catalysts from the lighter hydrocarbons and the converted hydrocarbon effluent to recover a hydrocarbon product and form a mixed catalyst comprising entrained hydrocarbons.
15. The process of claim 14, wherein the second reactor is a riser reactor.
16. The process of claim 14, further comprising stripping the entrained hydrocarbons from the mixed catalyst and feeding the stripped particulate catalyst to a catalyst regenerator.
17. The process of claim 16, further comprising regenerating the first and second particulate catalysts in the regenerator.
18. The process of claim 17, wherein the catalyst stream fed to the reactor and the second reactor comprises regenerated first and second particulate catalysts from the regenerator.
19. The process of claim 16, further comprising:

    feeding fresh second particulate catalyst to the reactor;

    feeding fresh first particulate catalyst to the regenerator.
20. The process of claim 14, further comprising feeding a mixture of first particulate catalyst and second particulate catalyst from the regenerator to the second reactor as the mixture of first and second particulate catalyst fed to the second reactor.

21. The process of claim 10, wherein the second particulate catalyst comprises ZSM-5 or ZSM-11, and wherein the first particulate catalyst comprises a Y-type cracking catalyst or an FCC cracking catalyst.
22. The process of claim 10, further comprising:

separating the hydrocarbon products into two or more hydrocarbon fractions including a light naphtha fraction and a heavy naphtha fraction; and

feeding the light naphtha fraction and the heavy naphtha fraction to the reactor.
23. A system for cracking hydrocarbons, comprising:

a mixing zone comprising:

a first inlet configured to receive a catalyst mixture comprising a first particulate catalyst and a second particulate catalyst at a first elevated temperature;

a second inlet configured to receive a catalyst stream comprising second particulate catalyst at a second lower temperature; and

an outlet configured to supply an admixture of the catalysts in the catalyst mixture and the catalyst stream to provide a mixed catalyst having a uniform intermediate temperature;

a reaction zone configured to:

contact the catalyst mixture having a uniform intermediate temperature with a light naphtha feed to produce a hydrocarbon-catalyst mixture at a second intermediate temperature;

contact the hydrocarbon-catalyst mixture at a second intermediate temperature with a heavy naphtha feed to produce a reactor effluent comprising first particulate catalyst, second particulate catalyst, and hydrocarbons;

a particle separator for separating second particulate catalyst from the reactor effluent to recover a hydrocarbon effluent stream comprising hydrocarbons and the first particles and the catalyst stream comprising second particulate catalyst; and

a feed line for returning separated second particles from the particle separator to the mixing zone.
24. The system of claim 23, further comprising:

a riser reactor for contacting a mixture of the first and the second particulate catalysts with a second hydrocarbon feedstock to convert at least a portion of the second hydrocarbon feedstock to lighter hydrocarbons and to recover a riser reactor

effluent comprising the lighter hydrocarbons and the mixture of the first and second particulate catalysts;

a separation system receiving the hydrocarbon effluent stream and the riser reactor effluent stream, the separation system separating the hydrocarbons contained therein from the first and second particulate catalysts; and

a regenerator for regenerating first and second particulate catalyst recovered in the separation system.

25. The system of claim 23, further comprising:

a stripper disposed intermediate the separation system and the regenerator for stripping additional hydrocarbons from the separated particulate catalysts, producing a stripped particulate catalyst, and for feeding the stripped particulate catalysts to the regenerator.

26. The system of claim 23, further comprising a second separation system for separating a hydrocarbon product stream recovered from the second separator into two or more hydrocarbon fractions including a light naphtha fraction and a heavy naphtha fraction.

27. The system of claim 24, further comprising:

a first feed line for feeding fresh second particulate catalyst to the reactor;

a second feed line for feeding fresh first particulate catalyst to the regenerator.